Center for Independent Experts (CIE) Independent Peer Review of the Bering Sea and Aleutian Islands Atka Mackerel Assessment

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Executive Summary

This report provides a review of the Bering Sea/Aleutian Islands (BSAI) Atka mackerel stock assessment. The 4 ToRs for the review are presented in the "Description of review activities and reviewer's role" section and focus on the input data, aspects of the assessment model and methodology (in particular, the treatment of selectivity, survey catchability, and natural mortality), and the application of assessment uncertainties in management advice. A review meeting took place at the Alaska Fisheries Science Center (AFSC), in Seattle, during July 29-31 2014, in which presentations on the different aspects of the assessment were given and discussions held.

The Aleutian Islands sustain an important commercial fishery on Atka mackerel, which started to develop during the 1970s and reached higher levels of catch from the early 1990s. The fishery has been restricted by measures to protect Steller sea lions, for which Atka mackerel constitute a main prey, and these measures have become stronger since 2011. The state of the Atka mackerel stock is assessed annually, using a statistical catch-at-age integrated model implemented in the software "Assessment Model for Alaska" (AMAK). Inputs to the assessment model are commercial fishery data (catch in weight and age compositions) and survey data (biomass indices and age compositions). Biological parameters (natural mortality, maturity, weight at age) are treated as known in the assessment. Substantial effort has been devoted to the treatment of the fishery selectivity process (modeled as age and time varying), and to the specification of the survey catchability q. Fishing mortality is estimated to have been less than $F_{40\%}$ throughout the assessment time series (starting in 1977), except in a single year. The recruitment trend is on the whole stable, but with particularly strong year classes in some years. In line with this, stock biomass also shows a stable trend on the whole, increasing appreciably in response to strong year classes. Stock biomass has been continuously decreasing since the mid 2000s, which was the time of highest stock biomass after three strong consecutive year classes during 1999-2001.

I consider the stock assessment to be consistent with best available science. My comments in this report pertain to aspects that I think would be interesting to explore, in order to try and gain additional understanding of those aspects (e.g. modeling methodologies or some specific features of the Atka mackerel assessment); some modifications to the stock assessment may follow after performing some of the explorations. There is, however, nothing that I feel needs to be urgently changed. A detailed discussion of my comments is provided later in this report and a complete bullet point list of suggestions and recommendations is presented at the end of the main body of this report. Here I provide a concise summary of only the points I identify as most relevant.

A difficulty with the survey data is that the patchy distribution of Atka mackerel and the fact that it forms dense schools occasionally produces large spikes in survey tows. It would be useful to explore if a more suitable method than a straight within-stratum average could be found for computing an abundance index. Mixture models or similar methods could be explored (see e.g. Thorson *et al*., 2011, 2012). A more involved possibility would be to try and develop a habitat model, characterizing the features associated with the distribution of Atka mackerel and how these features are distributed throughout the survey area. If such a model could be developed, then more precise prediction of Atka mackerel abundance in areas/stations not sampled could be obtained.

Concerning the modeling of the fishery selectivity as a stochastically varying process with correlation over ages and time, I suggest that a simulation-testing exercise would help to increase understanding of the properties of the method proposed. This would relate to the actual modeling of the selectivity over ages and time as well as to the method for estimating the standard deviation parameters.

Based on alternative assessment runs conducted during the review meeting with wider prior distributions on the survey catchability q, the conclusion is that prior assumptions made about q seem to have an impact on the estimated overall stock levels. It was said during the review meeting that a higher estimate of q could be a way for the model to reconcile highly variable survey biomass indices with other sources of data that do not indicate so much inter-year variability in the population. This seems to me like a feasible explanation for the high estimated q that arises when the prior distribution is taken to be wider. My impression after the explorations conducted during the review is that the prior distribution on q currently used for the Atka mackerel assessment (with CV=0.2) provides a sensible compromise that allows reconciling what might be considered as realistic based on expert knowledge and the possibly not entirely consistent signals arising from the different data sources.

Additional assessment runs were conducted during the review meeting, estimating an age varying M (constant over time) within the assessment model. From the results of these runs, it seems that the treatment of M in the stock assessment has the potential to influence stock perception and catch advice substantially. Given this, I suggest that careful examination would be needed before implementing any changes to this parameter.

A sensible alternative formulation for M could be to consider an age-dependent M selected outside the assessment model. Obvious options are the Lorenzen model (e.g. Lorenzen 1996), or the M-at-age formulation suggested in the report of the natural mortality workshop held at the AFSC in 2009 (the "best ad-hoc mortality model" in that report), see Brodziak *et al.* (2011). There was no time to explore this during the review meeting, but these alternative options seem worth exploring. An M-at-age vector could selected in this way and treated as fixed in the assessment model, or possibly the M-at-age vector could be estimated in the assessment model using a tight prior centered around the values first selected in this way (i.e. with Lorenzen's or the "best ad-hoc mortality model").

Finally, concerning the application of assessment uncertainties in management advice, AFSC scientists explained during the review that uncertainty is handled in the management advice for Alaskan stocks by having a buffer between the F used for the ABC and the F used for the OFL, the buffer being determined by the tier in which a stock assessment is classified. In line with this, the catch advice for the Atka mackerel stock is based on a point estimate of $F_{40\%}$, which is below the $F_{35\%}$ used for the OFL. This is a general buffer used for Tier 3 stocks, rather than a buffer directly accounting for the uncertainty in the assessment of the particular stock. From a scientific perspective, I consider the most appropriate treatment of uncertainty in management advice would be to realistically quantify assessment and projection uncertainty and then to have a management policy that defines what constitutes acceptable risk levels; the advice would then follow from the risk level specified in the policy, taking into account the (realistically quantified) assessment and projection uncertainty. I am aware that getting a truly realistic quantification of assessment and projection uncertainty is easier said than done and that managers are not always prepared to set risk levels. On the whole, I do not have any particular problem with the approach used to formulate management advice for the Atka mackerel stock, which provides a pragmatic way of dealing with the issues.

Background

The Aleutian Islands sustain an important commercial fishery on Atka mackerel, which started during the 1970s. Catches during the 1970s and 1980s were mostly between 20,000 t and 30,000 t, and subsequently increased to around 60,000 and 70,000 t in the mid-1990s. Catches remained at this higher level until substantial drops occurred, starting in 2011, due to regulations to protect Steller sea lions, for which Atka mackerel constitutes a main prey. Several measures have been enacted over the years to disperse Atka mackerel catches spatially and temporally (in order to avoid localized significant reductions at certain times), and to limit catches within Steller sea lion critical habitat. Since 1994 the TAC has been split into three management areas (Western Aleutian Islands; Central Aleutian Islands; Eastern Aleutian Islands/Southern Bering Sea). Bans on trawling within 10 or 20 nautical miles (depending on area) of Steller sea lion rookeries have been in existence for about twenty years. More restrictive fishery measures for the protection of Steller sea lions were introduced from 2011; in particular, directed fishing for Atka mackerel is not allowed in the Western Aleutian Islands area (with only a small TAC to cover bycatches in other fisheries), strong TAC restrictions are implemented in the Central Aleutian Islands area, and the Bering Sea subarea is closed year round to directed fishery for Atka mackerel.

The state of the Atka mackerel stock is assessed annually, using information from the commercial fishery and a bottom trawl research survey that takes place on a biennial basis since 2000 (it was triennial before that). The stock assessment covers the Aleutian Islands and the Southern Bering Sea. It should be noted that Atka mackerel is a schooling species and prefers rough and rocky bottom substrate, which makes surveying it by bottom trawl difficult, resulting in highly variable survey indices. The data used in the assessment are commercial catch, the survey biomass index, and age composition in the commercial fishery and in the survey samples; the age compositions are obtained applying age-length keys (by geographical area, where possible) to length frequency samples. An age-age matrix is used to account for age reading errors. Natural mortality, proportion mature and weight at age are also inputs to the stock assessment (treated as fixed values, not as parameters to be estimated within the assessment model). The stock assessment used Stock Synthesis before 2002, at which time it changed to the Assessment Model for Alaska (AMAK), which is the model currently used. AMAK is an integrated stock assessment model with generally similar features to Stock Synthesis (but with some differences too, e.g. concerning specific aspects of modelling selectivity). AMAK is programmed in AD Model Builder, and the software allows for maximization of the objective function (with the Hessian used to approximate the covariance matrix) or for its exploration via MCMC.

The assessment model follows the usual exponential equation for decay in abundance within cohorts, with catches-at-age modelled via the Baranov catch equation and with observation equations assumed to be log-Normal (for catch and survey biomass indices) and Multinomial (for age composition data). Detailed discussion of some aspects of the input data and assessment model is provided under the "Summary of findings for each ToR" section of this report.

The current Atka mackerel assessment model includes ages 1-11+ and assumes a constant natural mortality rate M=0.3 across ages and years. Annual recruitment (at age 1) is estimated in the assessment with annual deviates around a Beverton-Holt curve with steepness fixed at 0.8. The stock assessment document states that other values of the steepness parameter were explored in previous assessments and the assessment results were found to be insensitive to this assumption. The stock does not appear to have ever been reduced to levels that might produce reduced recruitment and be informative about steepness. The standard deviation of the annual deviates is estimated within the assessment, resulting in a value of 0.48. The assessment starts in 1977. The recruitment trend is stable on the whole, but the stock shows particularly strong year classes in some years. In line with this recruitment pattern, stock biomass is on the whole stable, but increases appreciably in response to strong year classes; this is particularly apparent following the consecutive 1999-2001 strong year classes. Stock biomass has continuously decreased since the mid 2000s, as these three year classes age and their abundance decreases. F is estimated to have been below $F_{40\%}$ throughout the entire time period, with the exception of a single year.

Atka mackerel is a mid trophic level species, and preys mainly on zooplankton. Regional and seasonal food habits data for the Aleutian Islands are very limited. From the available data, there seems to be a longitudinal gradient in the prey species mainly consumed (might this be related to the East-West gradient observed in Atka mackerel length-at-age, i.e. growth?). Predation mortality on Atka mackerel is estimated to be higher than fishing mortality, with Pacific cod and Steller sea lions as main predators.

The stock is in Tier 3. This means that the OFL is based on $F_{35\%}$ and the maximum ABC on $F_{40\%}$. The harvest control rule for the maximum ABC has F depend on the estimated value of current SSB in relation to reference points (with lower SSB implying lower F in the maximum ABC rule). In particular:

- If SSB $\geq B_{40\%}$, then $F=F_{40\%}$;
- If SSB $< B_{40\%}$, then F decreases linearly from $F=F_{40\%}$ when SSB$=B_{40\%}$ to F=0 when SSB$=0.05*B_{40\%}$;
- If SSB $\leq 0.05*B_{40\%}$, then F=0.

No directed Atka mackerel fishery is allowed if SSB $< B_{20\%}$; this is with the aim of protecting Steller sea lions, for which Atka mackerel is a main prey species.

Description of review activities and reviewer's role:

The review was organized around a meeting held at the AFSC, in Seattle, Washington, during July 29-31, 2014. The documents marked with (*) in the Bibliography section of this report were provided to the reviewers about two weeks in advance of the meeting and constitute the central material for the review. Additional documents were made available during the meeting and are also all listed in the Bibliography.

The meeting followed quite closely the planned agenda of presentations, developing as follows:

Tuesday, July 29, 2014
The following presentations were given by ASFC scientists (each of them was followed by questions and discussion):

- Management and general modeling approach.
- Overview of Atka mackerel: the fish and the fishery.
- North Pacific Observer Program Sampling Design: BSAI Atka Mackerel.
- Atka Mackerel Age and Growth at AFSC.
- Aleutian Islands Bottom Trawl Survey (1980 – present).
- Aleutian Islands Ecosystem Overview.
- Stock assessment model used for Atka mackerel.

Wednesday, July 30, 2014
The morning was spent on continuing discussions from presentations of the previous day, in addition to having one more presentation:

- Stock assessment of Aleutian Islands Atka mackerel.

In the afternoon alternative model runs and requests for other assessment aspects to be explored during the review meeting were formulated.

Thursday, July 31, 2014
Results from requests made on the previous day were finalized during the morning and the results discussed in the afternoon. This concluded the meeting.

The following ToRs were given for the review process, as points that needed to be addressed in the reviewers' reports:

1. The strengths and weaknesses of the modeling efforts for the Bering Sea and Aleutian Islands Atka mackerel assessment and harvest recommendations. Specifically, the review shall evaluate:

    a) The analysts' use of fishery dependent and fishery independent data sources in the assessments;
    b) Gaps or inconsistencies in the population dynamics modeling methodology or logic;
    c) How assessment uncertainties may best be applied for management advice; and
    d) Whether the assessments provide the best available science.

Additionally, the review shall (to the extent practical) evaluate and provide advice on:

2. The specification of time-varying and age-specific selectivity parameters

3. The treatment and application of survey data; specifically

    a) Survey biomass estimates by management areas as used for quota apportionments; this stock forms dense patchy schools resulting in high variability

    b) Survey catchability

4. The incorporation of age differential natural mortality and the interaction with selectivity and survey catchability parameters

All three reviewers fully participated in all aspects of the review. The procedure I followed to provide this independent review report was to read carefully in advance the documents provided for the review, then to exchange views and clarify questions with AFSC scientists and the other reviewers during the meeting and, finally, to review some documents once again (benefiting from the insights gained during the meeting) and go through additional literature as a follow up to some of the discussions held during the meeting.

AFSC scientists were very helpful clarifying doubts and questions during the discussions that took place at the meeting, and I felt the review meeting provided a very good platform for learning and exchanging views between all of us there. I found the experience very interesting and rewarding, and I am grateful for the opportunity to take part in this review.

Summary of findings for each ToR:

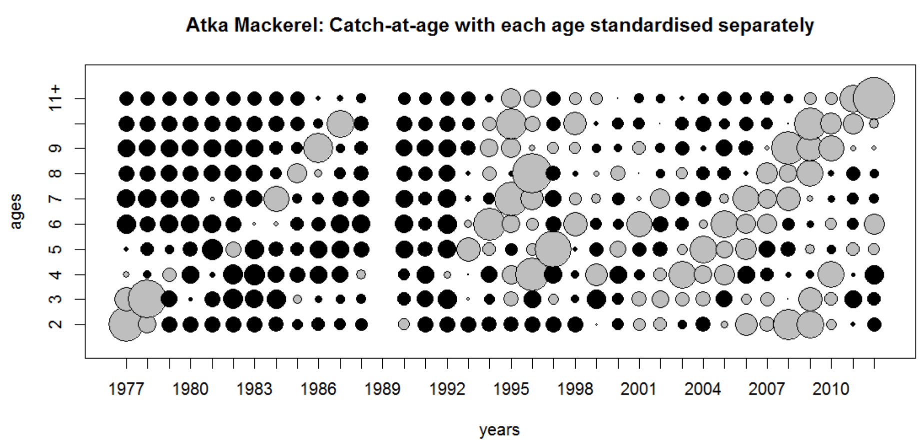
This section presents the main points that arose during the review, according to my own perspective and understanding of the issues discussed. Thoughts from following up (after the meeting) on some aspects of the work presented and discussed there, are also included. This section is organized following the ToRs.

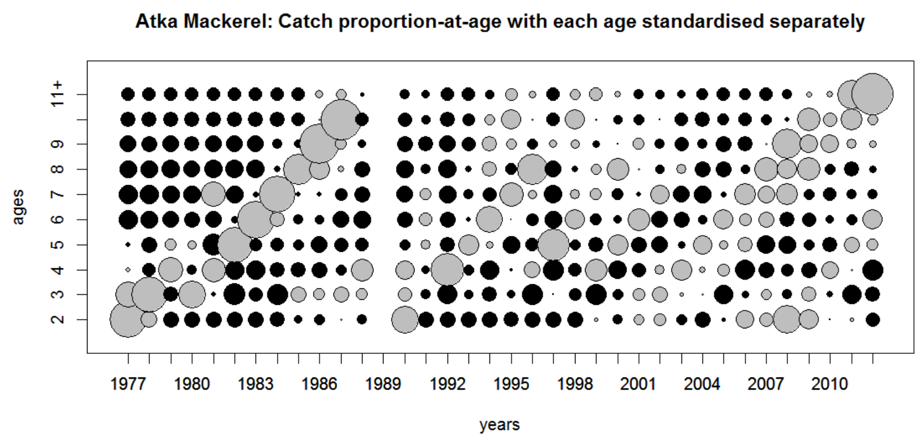
ToR 1. The strengths and weaknesses of the modeling efforts for the Bering Sea and Aleutian Islands Atka mackerel assessment and harvest recommendations, focusing on the four points provided below.

a) The analysts' use of fishery dependent and fishery independent data sources in the assessments

The two main sources of data used in the assessment are: fishery dependent data (annual commercial catch tonnage and age compositions, starting in 1977) and fishery independent data (bottom trawl survey, which provides a biomass index and age compositions). AFSC scientists gave presentations about each of these data sources.

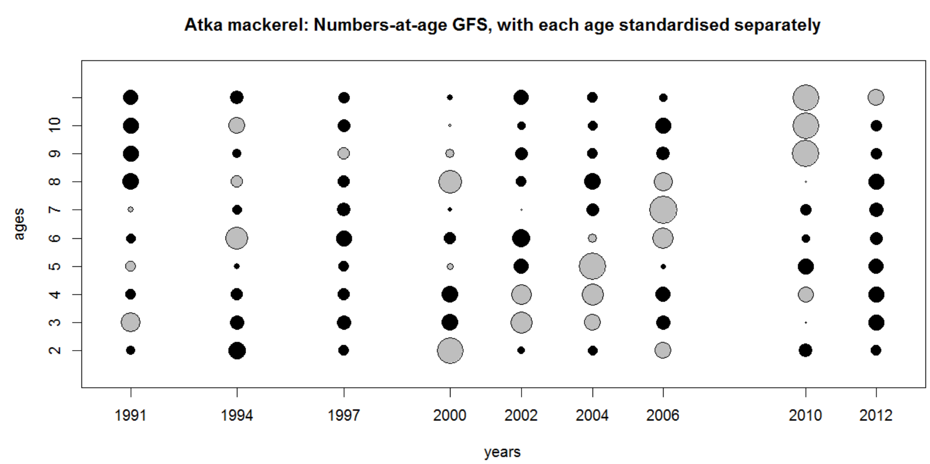
The fishery dependent data are collected by observers onboard fishing vessels. For Atka mackerel, the observer coverage is very high and there seem to be no major issues that would cause concern about the quality and representativeness of the data collected. An AFSC team of scientists working on growth reads the otoliths; the methods employed and the process followed to quality-check the results were explained and, although I am not an expert in this, they seemed to do a thorough job. The aim is to construct a separate age-length key for each geographical area (Western Aleutians; Central Aleutians; Eastern Aleutians and Southern Bering Sea). Separate age-length keys are appropriate because of the different growth observed in these areas, with individuals being larger (for the same age) in the east than in the west. The resulting matrix of catch-at-age data for the stock assessment clearly tracks the main cohorts going through the population and it is likely to be the most informative data source available for the assessment. Below I present two bubble plots that illustrate this point (I am aware that most assessment scientists will have their own preferred method for visualizing and understanding data signals!). The top and bottom plots represent catch numbers at age and annual catch proportions at age, respectively (values were calculated from the catch-at-age matrix in Table 17.4 of the 2013 assessment report, see Lowe *et al.* 2013). In both plots, each age is standardized separately, by subtracting the mean (for that age) over the time series and dividing by the standard deviation (for that age) over the time series; grey and black bubbles represent values above and below average, respectively, and the area of the bubble is proportional to the magnitude of the value:

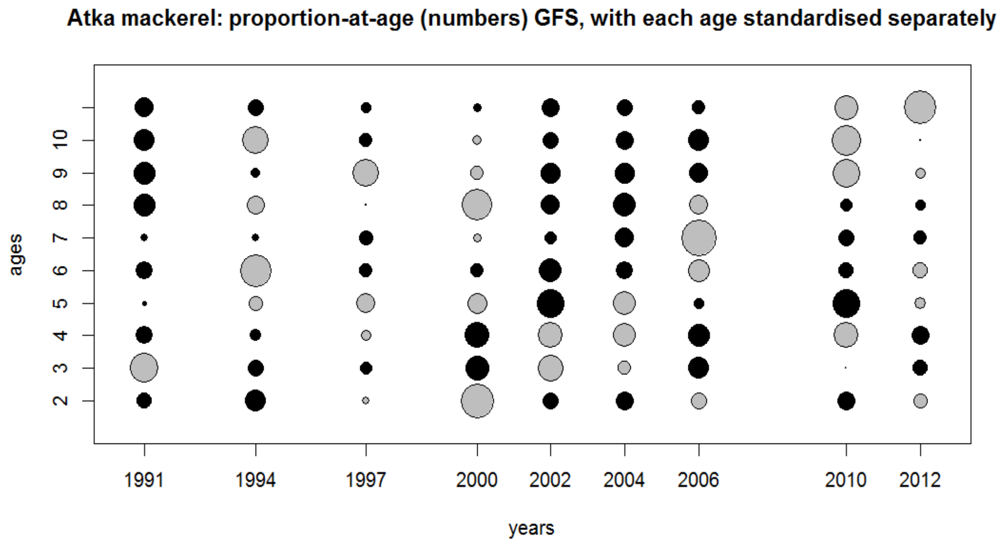




Length frequency distributions from the commercial fishery (Figures 17.2 and 17.3 of the 2013 stock assessment document) clearly indicate that Atka mackerel are larger towards the east than in the west, and several studies conducted in the past indicate that this is due to differences in growth. The reviewers asked whether age frequency distributions (i.e. not just the length frequency distributions) may also differ between areas; understanding this would be relevant, particularly given the geographical restrictions acting on the fishery in recent years due to Steller sea lions protection measures. We were told that no particular differences had been detected in the age composition data of different areas, but that this would be explored in more detail for future assessments. I agree that further examination of this would be useful.

The fishery independent data are collected via a bottom trawl survey, conducted on two chartered vessels, with a survey design developed by AFSC scientists and standardized survey gear. The survey was conducted triennially during the 1980s and 1990s and biennially since 2000. The early survey years are not used in the assessment, because the survey did not cover main areas of Atka mackerel abundance; this seems appropriate to me. The survey catches in numbers-at-age (from 1991) and annual proportions-at-age are shown in the following figures (each figure is standardized for each age separately, as explained for the previous bubble plots):





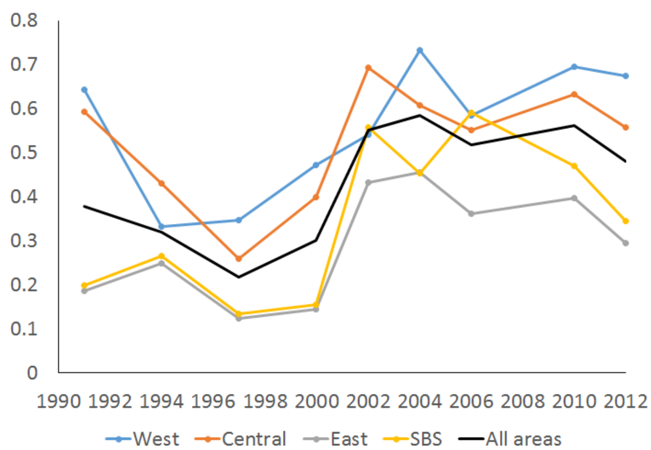
The top plot suggests that 2012 and 1997 could be "year effects" in the survey, since the bubbles are black (i.e. the observed survey value is below the time series average) for almost all ages in those years. The plots also illustrate that the age structure of the survey indices can at least also track the main cohorts.

There was a lot of discussion about the Atka mackerel survey biomass indices during the review meeting (note: the discussion referred mainly to the biomass indices, not to the age structure). The survey design is optimized based on 14 different species, not just Atka mackerel. In addition, Atka mackerel displays a rather patchy distribution, tends to school, and is often found on rocky bottoms that are not easily accessible to the survey. There seems to be little overlap between the survey and the main fishery areas. Figure 17.6 of the 2013 stock assessment report illustrates the patchy nature of the survey catches and the very large spikes that occur when a dense school is encountered in a tow. This makes the survey biomass index rather uncertain, particularly in the eastern area (see Figure 17.4 of the 2013 stock assessment report).

The survey biomass index for Atka mackerel is computed as a weighted average, based on the mean survey CPUE per stratum, with the weights proportional to the strata areas. There are 45 strata, reflecting combinations of management areas and depth ranges. Given the patchy distribution of Atka mackerel, and the very large spikes encountered in some survey tows, it would be useful to explore if a more suitable method than a straight within-stratum average could be found for computing an abundance index. Mixture models or similar methods could be explored (see e.g. Thorson *et al*., 2011, 2012). A more involved possibility would be to try and develop a habitat model, characterizing the features associated with the distribution of Atka mackerel and how these features are distributed throughout the survey area. If such a model could be developed, then more precise prediction of Atka mackerel abundance in areas/stations not sampled could be obtained.

The following aspect was only mentioned in passing during the review meeting, but having thought about it afterwards, I think it would be worth exploring. I understood that the observation equation for the observed biomass index in the assessment model is log-normal with median equal to the model-predicted biomass index value. However, it seems to me that the survey index has been constructed to be an unbiased estimator of the model-predicted value and, therefore, it would seem more appropriate to consider the mean, rather than the median, of the log-normal observation equation as equal to the model-predicted value. I find it difficult to guess what the impact of this change would be on the stock assessment, but given the different CVs in different years (ranging from 14% to 35% during 1991-2012), I expect it will have some impact and I think understanding this would be relevant.

An unexpected (at least to the reviewers) pattern in the proportion of positive Atka mackerel survey tows was uncovered during the review meeting. This is shown in the figure below, and illustrates an increase in the proportion of positive tows starting in year 2002. This increase was first considered to be counterintuitive because in 2002 the tows shifted to 15 minutes duration from the previous 30 minutes duration and, all other things being equal, this change would be expected to result in a lower proportion of positive tows (which is the opposite from what has been observed). After discussion with AFSC scientists, the conclusion is that this is most likely arising from a combination of factors: the three very strong year classes occurring in sequence during 1999-2001, which led to a population increase; some range expansion to the east for Atka mackerel over the last 10 years; the fact that by towing for only 15 minutes it may be easier to get closer to rougher bottoms, favored by Atka mackerel (although the vast majority of survey stations are drawn from the pool of trawlable stations sampled in previous surveys). The latter of these three possibilities could suggest an increase in the survey catchability, which would have to be taken into account, but since most stations are drawn from the pool of previously trawled stations, I suspect this is not a major issue. After these explanations I do not think additional investigation would be required.



b) Gaps or inconsistencies in the population dynamics modeling methodology or logic;

The stock assessment uses an age-based population dynamics model, where recruitment (age 1) follows a Beverton-Holt stock-recruitment curve with annual stochastic deviations. Given recruitment, M and F, the remaining abundances at age in the cohort follow deterministically from the standard exponential decay equation (however, F is modelled stochastically, over ages and time, as will be later discussed). Catch numbers-at-age are obtained from the standard Baranov catch equation, and then transformed to total catch biomass and proportions at age for comparison with the observed data. The observation equations are lognormal for the catch biomass and multinomial for the catch proportions at age. There are also observation equations for the survey data: these are lognormal for the survey biomass index and multinomial for the proportions at age. Age-reading error is also taken into account in the transformation from model to observed age compositions.

I consider this modelling framework as fairly standard and totally appropriate for the Atka mackerel assessment.

What is less standard is the way selectivity-at-age is modelled over ages and time. As ToR 2 of this review focuses specifically on this aspect, I will comment on this under that ToR.

The software used to implement the assessment model is AMAK ("Assessment Model for Alaska"). The AMAK code is written in AD Model Builder and it either finds the maximum of the likelihood/posterior surface and applies the usual approximation to the variance-covariance matrix based on the Hessian, or explores the likelihood/posterior surface via MCMC. My main background is on what I would call "more standard" Bayesian methods (such as performed with BUGS), and I sometimes find it difficult to understand what exactly the statistical properties of the algorithms and overall procedure used by AMAK are. My comment refers mainly to the fact that there can be multiple stochastic distributions on the same quantity (e.g. recruitment (which has stochastic deviations from a Beverton-Holt curve and also seems to have stochastic deviations from a constant value), or several stochastic smoothing penalties on the selectivity). It is not entirely clear to me which of the properties I am familiar with for "standard" posterior distributions or for maximum likelihood estimators I should expect here. I am not suggesting any specific action, but the assessment authors could perhaps provide some explanations in this respect in future assessment documents, or as part of the AMAK documentation (some methodological references could help).

c) How assessment uncertainties may best be applied for management advice;

ToR 1b already indicates how uncertainties are dealt with in the assessment. Uncertainty enters as part of the assessment inputs via the CV of the observation equations for total catch tonnage and survey biomass index, as well as via the sample sizes used for the multinomial observation equations for age composition data. These CVs and multinomial sample sizes are fixed inputs to the assessment and not estimated or changed as part of running the stock assessment model. The issue of what values would be appropriate for the CVs and the multinomial sample sizes was not revisited during this review. The CV for the survey biomass index and multinomial sample sizes for the commercial catch data appear to have been chosen based only on sampling variability and do not account for additional uncertainties in terms of how well the observed data may represent the true quantities. I think it would be interesting to explore what would happen if an extra component was added to the variability, in order to represent departures between observed data and real quantities not already encapsulated by the sampling variability; this extra component would be a parameter estimated within the stock assessment. However, I do not regard this as something urgent.

Stochasticity is also incorporated in the assessment via annual deviations from the stock-recruitment curve (the variance associated with these deviations is a parameter estimated within the assessment model), and also via the selectivity (stochastically varying over ages and time; the variance associated with this is also estimated, as will be discussed under ToR 2). The survey catchability, q, is also given a (fairly tight) prior distribution. M, maturity-at-age and weight-at-age are considered known without error (as is the case for most stock assessments I am familiar with).

In my opinion, this leads to a reasonable treatment of uncertainty within the assessment.

The assessment output displays the uncertainty associated with relevant stock parameters (biomass, SSB, recruitment), but this uncertainty is not carried over to the catch advice, which is based on single point estimates from the assessment and a single value of $F_{40\%}$. AFSC scientists explained during the review that uncertainty is handled in the management advice for Alaskan stocks by having a buffer between the F used for the ABC and the F used for the OFL, the buffer being determined by the tier in which a stock assessment is classified. Following from this, the catch advice for the Atka mackerel stock is based on a point estimate of $F_{40\%}$, which is below the $F_{35\%}$ used for the OFL. This is a general buffer used for Tier 3 stocks, but, of course, it does not directly account for the uncertainty in the assessment of the particular stock. From a scientific perspective, I consider the most appropriate treatment of uncertainty in management advice would be to realistically quantify assessment and projection uncertainty and then to have a management policy for what constitutes acceptable risk levels; the advice would then follow from the risk level specified in the policy, taking into account the (realistically quantified) assessment and projection uncertainty. I am aware that getting a truly realistic quantification of assessment and projection uncertainty is easier said than done and that managers are not always prepared to set risk levels. On the whole, I do not have any particular problem with the way management advice is currently formulated for the Atka mackerel stock, which provides a pragmatic way of dealing with the issues.

There is one exception to my comment that management advice relies on single point estimates, which is that the probability that future SSB may be less than $B_{20\%}$ is also calculated. If I understood it correctly, the required probability is calculated based on stochastic projections, projecting the population into the future using each of the MCMC draws obtained from fitting the stock assessment model (so there is uncertainty in population numbers-at-age and selectivity-at-age, with correlations between variables treated coherently because MCMC draws from the same iteration are taken forward into the projection together). In each projection year, recruitment is stochastically generated and the corresponding harvest control rule applied. The required probability is just the proportion of draws for which the projected SSB is $< B_{20\%}$. This stochastic projection approach seems appropriate to me. It was noted during the review that this projection approach does not account for sources of error, such as assessment error, wrongly specified M, etc. Including all these errors would lead to a much more involved procedure, closely resembling a Management Strategy Evaluation, which I would not think is needed at this stage. Taking into account that the stock is assessed every year (so there is plenty of opportunity to detect unexpected changes and to react to them if considered necessary), and assuming that the probabilities calculated by the current stochastic projection method are low, I would think no additional complexity is necessary.

d) Whether the assessments provide the best available science.

I consider the stock assessment to be consistent with best available science. I would like to stress that my comments in this report refer to aspects that I think would be interesting to explore, in order to try and gain additional understanding of those aspects (e.g. modeling methodologies or some specific features of the Atka mackerel assessment); some modifications to the stock assessment may follow after performing some explorations. There is, however, nothing that I feel needs to be urgently changed.

ToR 2. The specification of time-varying and age-specific selectivity parameters.

Fishery selectivity in this assessment is considered to vary with age and time. In a given year, the first difference of the log(selectivity at age) [i.e. $\log(\mathrm{sel}_{y,a}) - \log(\mathrm{sel}_{y,a-1})$, where $\mathrm{sel}_{y,a}$ is the selectivity at age a in year y], is assumed to follow a Normal distribution centered at the first difference of the previous ages (in the same year) [i.e. centered at $\log(\mathrm{sel}_{y,a-1}) - \log(\mathrm{sel}_{y,a-2})$]. Therefore, the distribution of the log(selectivity) in each year is centered around a straight line over the ages; the log(selectivity) values actually estimated will, of course, deviate from a straight line based on the information provided by the data used in the stock assessment. The log(selectivity) is concurrently assumed to be auto-correlated over the years, with a Normal distribution centered on the values in the previous year. Once again, the log(selectivity) values actually estimated for a given year will typically deviate from those in the previous year, based on the information provided by the data used in the stock assessment. There is also a stochastic penalty on older ages, which tries to prevent excessive dome shapes in selectivity. Finally, the selectivity of the plus group is assumed equal to that of the last true age.

The basic idea, which is to model selectivity as a correlated process over ages and time, seems sensible to me, and the way in which the idea has been implemented in the Atka mackerel assessment also seems in principle reasonable. An age and time varying selectivity, but with constraints on the form of the variability, lies between a VPA approach (where catch-at-age is assumed to be known exactly and selectivity is allowed to vary without any constraints so that a perfect fit to the catch-at-age data is provided) and a separable approach (where catch-at-age is only known subject to error and fishing mortality is assumed to be the product of a year factor and a time-invariant age factor). There are several ways in which a constrained age and time varying selectivity could be implemented in the stock assessment model. One possibility is to have time blocks within which fishing mortality is separable. This was implemented for the 2008 – 2012 Atka mackerel assessments, but the assessment authors have now reverted to modelling the selectivity as a process varying over ages and time in a stochastically constrained way, as described in the previous paragraph. This seems fine to me; I generally prefer to avoid assumptions based on blocks, which keep parameters constant within a given block and may lead to considerable changes between blocks, unless there is a clear rationale supporting the particular choice of blocks (that said, in the Atka mackerel case there seemed to be a reasonable rationale for the four time blocks used in the 2008-2012 assessments, based on fishing fleet composition and regulations). In my paper Fernández *et al.* (2010), I used a combination of time blocks and stochastically time-autocorrelated selectivity, although each age was modelled separately (i.e. no prior correlation between ages). The model SAM (https://www.stockassessment.org/login.php, developed by A. Nielsen) also treats selectivity as varying stochastically over time; my understanding is that correlation between ages (in addition to time-autocorrelation), is incorporated as an option in the SAM software, although with the same between-age correlation value for all ages (i.e. I do not think SAM assumes higher correlation between ages that are closer together than between ages that are further apart).

My only question about the selectivity model and fitting methodology used for Atka mackerel is that I do not fully understand what the surface that is being optimized means (this relates to my comment under ToR 1b). Because of my, say "more standard", Bayesian background, as I noted before, normally I would formulate this type of process for selectivity by introducing auxiliary variables $\mathrm{diff}_{y,a}$ (representing the first difference of log(selectivity) between ages a and $a-1$, i.e. $\mathrm{diff}_{y,a} = \log(\mathrm{sel}_{y,a}) - \log(\mathrm{sel}_{y,a-1})$), where $\mathrm{diff}_{y,a}$ has a Normal distribution centered at $\mathrm{diff}_{y,a-1}$ and with some standard deviation σ_{age}. Then I would define $\log(\mathrm{sel}_{y,a}) = \log(\mathrm{sel}_{y-1,a}) + \sigma_{time} \sum_{j \le a} \mathrm{diff}_{y,j}$. AR(1) processes, with some autocorrelation parameters ρ_{age} and ρ_{time}, could also be used instead of random walks. The idea is to arrive at a single stochastic definition of $\mathrm{sel}_{y,a}$; the $\mathrm{diff}_{y,a}$ variables would be akin to random effects (or, say, nuisance parameters) that would need to be integrated out. Whereas I understand that one can formally multiply the several Normal distributions that are being proposed for log(selectivity) in the Atka mackerel assessment (over ages, time, and to avoid excessive dome shapes) and then find the maximum of the resulting surface, I am not sure whether the statistical properties of that surface are well known. I am aware this type of approach is not infrequent in stock assessments, so I imagine the properties have been studied and are known, but some references in this respect (in the assessment report or the software documentation) would be useful. Alternatively, I would suggest conducting a simulation exercise with underlying known selectivity (with age and time correlation), simulating fish populations and assessment data, to gain understanding of how well the methodology does at recovering the true underlying values of selectivity and relevant stock assessment parameters and quantities used in management advice; this would be similar to the simulation-testing exercise conducted for the WCSAM workshop held in Boston in July 2013 (http://www.ices.dk/news-and-events/symposia/WCSAM-2013/Pages/Structure.aspx); see also Deroba *et al.* (2014).

I have a similar comment (i.e. about exploring the properties of the methodology via simulation-testing) regarding the way the standard deviation of the time and age correlation process for log(selectivity) is estimated. During the review meeting, it was explained that estimation of σ_s followed a 3-step approach:

1. Estimate the log(selectivity) coefficients unconstrained (i.e. assuming a large value of σ_s in the stock assessment). Label the matrix of resulting log(selectivity) estimates $\boldsymbol{s}$.
2. Estimate σ_s iteratively from the stock assessment. Call this value $\dot{\sigma}_s$.
3. Obtain a final estimate of σ_s as $\hat{\sigma}_s = \sqrt{\mathrm{var}(\boldsymbol{s}) - \dot{\sigma}_s(\sqrt{\mathrm{var}(\boldsymbol{s})} - \dot{\sigma}_s)}$

The only document that I could find providing some background to this estimation procedure was Annex 2.1.1 of the December 2012 Pacific cod assessment (Thompson and Lauth, 2012). From that annex and from the explanations provided during the review meeting, my understanding is that the 3-step method essentially tries to estimate σ_s in a way that approximates the estimated value it would have if the log(selectivity) parameters were treated as random effects and integrated out, but without actually performing that integration (i.e. in reality optimizing over the random effects, instead of integrating them out). The problem seems to be that when the log(selectivities) are treated as parameters to be optimized, the maximum likelihood estimate of σ_s (which is the $\dot{\sigma}_s$ obtained in step 2 of the 3-step method) is biased low; therefore, step 3 is performed in order to obtain a larger estimate of σ_s. The estimate obtained in step 3 should be an approximation to the value that would be estimated if the log(selectivities) were treated as random effects and integrated out.

I went over the formulas presented in the Pacific cod assessment annex and tried to replicate them, since, as far as I can see, they seem central to the formula used for $\hat{\sigma}_s$ in step 3. I could not replicate equation (2.1.1.2) from the annex nor the formula immediately above it (which is not numbered). The calculations are intricate and it is easy to make a mistake, which I may well have done (or possibly I misunderstood some aspect of the derivation). Nevertheless, I would recommend that the assessment authors go over the derivations in that annex once again, just to make sure that they are correct. As I noted above, I also feel that a simulation-testing exercise would be very helpful to gain better understanding of the performance of this method.

Finally, applying the 3-step methodology above, the resulting value of $\hat{\sigma}_s$ for the Atka mackerel assessment is about 0.95 (the same value is used for both ages and time). Because this is the standard deviation on the log(selectivity), it means that the CV of the selectivity is about 1, and this is allowing for substantial departures from the central value of the distribution. It was noted during the review meeting that individual MCMC selectivity samples looked rather variable over the ages (for a given year) and I imagine it is due to this high CV value. On the other hand, the median selectivity estimate was smoother, and that (or, in any case, a single point estimate of the selectivity) seems to be what is carried forward to the catch projections and reference points calculations, as discussed under ToR 1c (except for calculating the risk of SSB falling below $B_{20\%}$, which is based on stochastic projections, so I imagine the MCMC selectivity samples are taken forward in that case).

ToR 3. The treatment and application of survey data; specifically

a) Survey biomass estimates by management areas as used for quota apportionments; this stock forms dense patchy schools resulting in high variability

I have already addressed the use of survey data in the stock assessment under ToR 1a (in the second part of the ToR). My comments here relate to the method used to split the ABC for the Atka mackerel stock into 3 fishing districts (western Aleutian Islands; central Aleutian Islands; eastern Aleutian Islands and southern Bering Sea).

A separate TAC has been set for each of the 3 fishing districts since the early 1990s, with the aim of preventing localized overfishing and potential depletion, even on a temporary basis (as this could impact on prey availability for Steller sea lions during the time, and for some time after, the fishery takes place). The 2013 stock assessment document indicates that the split is based on the 4 most recent trawl surveys (in the 2013 assessment these were survey years 2004, 2006, 2010 and 2012; there was no survey in 2008). The proportion of total survey biomass in each of the 3 regions is calculated for each of the 4 survey years. Subsequently, a weighted average of the proportions observed in the 4 years is calculated for each region, and the result is used to split the ABC. The weights differ by year as follows: the weight given to the most recent survey is 1.5 times higher than the weight given to the previous survey, which is in turn 1.5 times higher than the weight given to the previous survey, and so on.

No rationale for this methodology was provided in the 2013 stock assessment document. During the review meeting it was explained that this is based on a Kalman filter type of reasoning, and Attachment 2A from the Pacific cod assessment of 2004 (Thompson and Dorn, 2004) was provided as the document describing the method used. We were also told that a working group has been tasked with conducting an in-depth examination of potential methods to do these splits, so I feel that the working group should be able to provide more insightful proposals than what was possible during the short time of the CIE review.

Nevertheless, I read the Pacific cod Attachment 2A to get a better understanding of the rationale that led to the choice of the factor 1.5 between the weights of subsequent survey years. Following the "Exponential weighting" method described in that Attachment, the weight of a survey year is $1/(1-p)$ times the weight of the previous survey year; the value 1.5 used for Atka mackerel therefore corresponds to $p = 1/3$. The Attachment also explains that this type of weighting can formally be interpreted as the weights that would be obtained from a Kalman filter, under several assumptions, namely: intercept=0 and slope=1 both in the transition and the observation equations (of a state-space model for the proportion of stock biomass in a fishing district, with the survey biomass index for that district constituting the observation); process error and measurement error variances are constant over time; observations are evenly spaced in time. Under these assumptions, the Kalman filter results in exponential weighting with $p = 2/(1+\sqrt{1+4r})$, where r is the measurement error variance divided by the process error variance (I did not check this formula, I assume it is correct; intuitively it works as I would expect, as lower values of r lead to higher values of p and, hence, also to higher relative weights for a survey versus the previous survey; in the limit when r goes to 0, p goes to 1 and only the most recent survey would be used to predict stock biomass, which also makes sense to me). Not all the assumptions noted above hold for Atka mackerel: the observation error from the survey is not constant over time and the survey observations are not equally spaced in time (as year 2008 is missing); the Kalman filter algorithm can be extended to cope with these departures, as the Pacific cod Attachment also indicates. For the sake of simplicity, here I just calculate the value of r that would correspond to $p = 1/3$ (as used for Atka mackerel) if all the assumptions above held. This results in $r = 6$ or, in other words, the standard deviation of the measurement (survey index) error is assumed to be 2.45 times the standard deviation of the process error (which here refers to how the true biomass proportion in a given fishing district changes over time). Given the high variability in the survey (i.e. the high observation error), these values do not seem inappropriate at first sight.

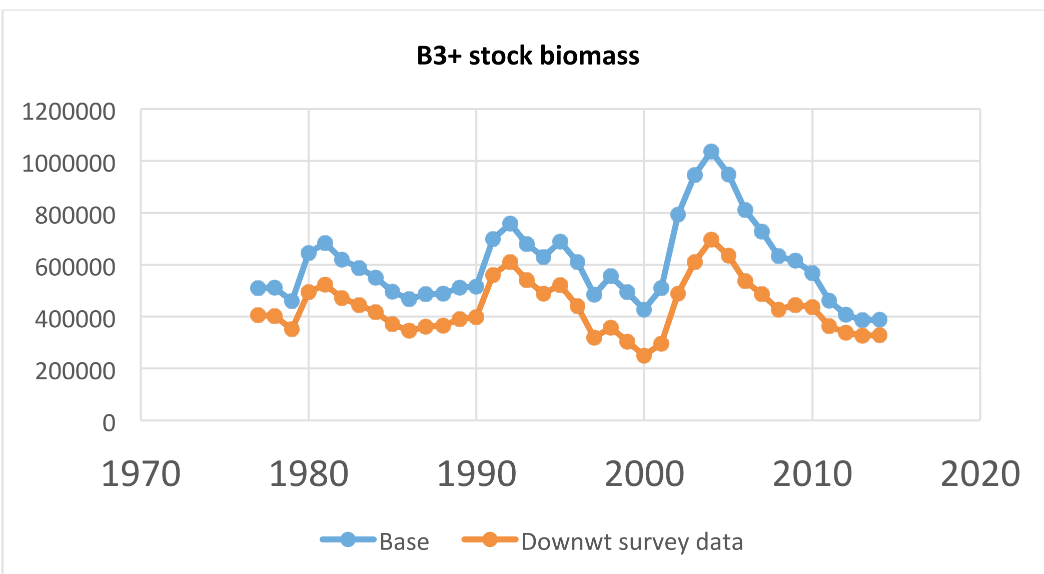
However, as the assessment authors indicated during the review, I suggest waiting for the results of the working group specifically dealing with methods for this, as more appropriate ways to perform the split may be found.

b) Survey catchability

This was explored in some detail during the review meeting. Given the high variability observed in the survey, there was a feeling that the survey biomass indices may not be contributing very much to the stock assessment estimates. At the same time, a rather tight prior on the survey catchability q is assumed in the assessment (log-normal prior with median equal to 1, and standard deviation for log(q) equal to 0.2; i.e. approximately 20% CV on q). During the review were interested in understanding two main aspects:

- contribution of survey biomass indices to the assessment estimates (is it substantial or not?)

Assessment runs were conducted during the review meeting, downweighting the survey biomass index data (which I think was done by increasing the CV of the log-normal observation equation). Although this did not change the estimated stock trends strongly, it changed them somewhat, with the stock biomass decreasing less strongly after 2004 when the survey biomass indices were downweighted (see next figure, which compares the estimated the 3+ stock biomass in the base case (i.e. the current assessment) with the case where the survey biomass index data are downweighted). Downweighting the survey biomass index data resulted in a lower estimate of stock biomass overall; in this case, the survey catchability q was estimated to be 1.06, which is rather close to its prior mean of 1.02, as opposed to 1.2, which is the estimate of q in the base case. Having thought about these results again after the meeting, I find it surprising that a lower stock biomass estimate is associated with a lower estimate of q (I would, in principle, expect to see negative correlation between the estimates of q and stock biomass). I wonder whether this result here may be related to the fact that the log-normal observation equation for the survey has the model-predicted biomass index value as the median rather than the mean; this can have an impact when the CV is altered, as changing the CV also changes the distance between the mean and the median of the log-normal distribution. I suggest exploring this issue further, repeating the same exploration conducted during the review meeting but keeping the same mean (instead of the same median) for the log-normal observation equation of the survey biomass index.



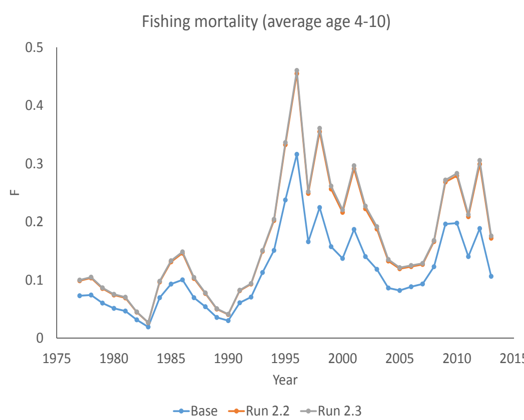
- effect of prior on catchability (is the prior too tight and may it be influencing assessment results too much?)

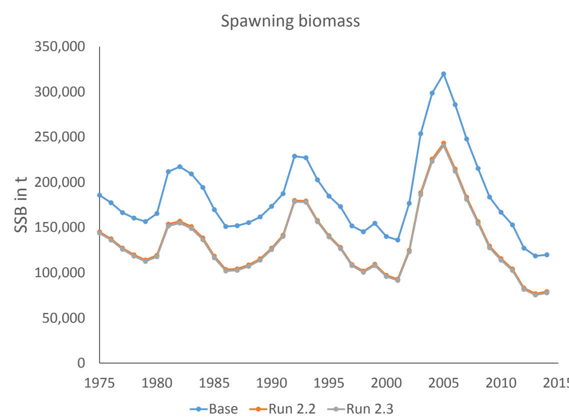
For this exploration, the survey biomass index data were not downweighted, but the following priors were used on q:

	Priors			Results		
Run	Median	Sigma	Mean	lnq	Sigma lnq	q
Base	1.000	0.200	1.020	0.18212	0.210	1.199758
Run 2.2	0.741	0.800	1.020	0.58282	0.205	1.791082
Run 2.3	1.000	0.800	1.377	0.60206	0.200	1.825876

The first prior (denoted "Base") is the one currently used in the Atka mackerel stock assessment. It has median and mean both very close to 1 and 0.2 standard deviation on log(q) [hence, the prior CV of q is approximately 20%]. The assessment estimates q at 1.20 (see right-most column of table above).

Two alternative runs loosened the prior on q (by increasing the standard deviation of log(q) to 0.8). In Run 2.2, the prior mean of q was kept equal to the Base case, whereas in Run 2.3 it was the prior median of q that was kept as in the Base case. In both cases, the assessment estimates q close to 1.8 (right-most column of table above). As would normally be expected with a larger estimated value of q, the estimated SSB becomes lower overall and the estimated F becomes higher overall (although the trends are unchanged); this is illustrated in the figures below (the red and grey lines coincide).





This indicates that the prior chosen for q has an impact on the assessment results. The impact is on the overall levels, rather than on trends. Loosening up the prior on q (which is what I would normally do by default), produces estimates of q at around 1.8 and the question is whether this value is too high to be considered realistic. The prior on q is constructed around the idea that q should be somewhere around 1; as a starting point, this seems logical to me for this survey index, based on swept area. I would suggest exploring this further. For example, what happens if the prior on q is widened even more? Does the estimate of q then still converge towards 1.8 (so that we can say this is the value most consistent with the data information currently available), or does the estimate of q continue to increase as the prior becomes even wider? I also think it would be interesting to conduct a retrospective analysis with the wider priors on q (the priors used for Runs 2.2 and 2.3): how does the q estimate change retrospectively? could it be that the very low survey biomass index in 2012 is causing q to increase?

At present, overall stock levels do not seem to be well determined, and I wonder whether this has always been the case or whether it is, on the contrary, something that has arisen mostly as a consequence of the low 2012 survey biomass index. The assessment authors indicated during the review that they had observed an increasing pattern in the q estimates with each new assessment, so I imagine the issue of uncertain overall stock levels is not a new phenomenon. It was also said during the review meeting that a higher estimate of q could be a way to reconcile highly variable survey biomass indices with other sources of data that do not indicate so much inter-year variability in the population. This could be a feasible explanation for the high estimated q.

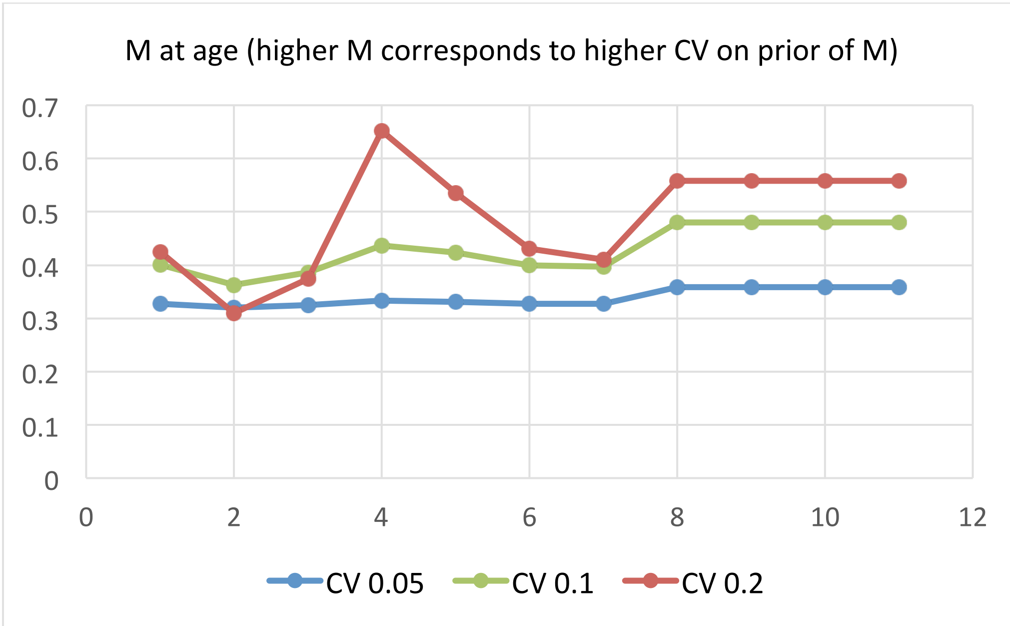
Based on the information seen during the review, my impression is that the prior distribution on q currently used for the Atka mackerel assessment (with CV=0.2) provides a sensible compromise that allows reconciling what might be considered as realistic based on expert knowledge and the possibly not entirely consistent signals arising from the different data sources.

$F_{40\%}$ was computed based on the selectivity estimated with the wider prior on q in Run 2.2, and found to be a bit higher than in the base case. Therefore, there may be some compensation when it comes to catch advice (lower stock abundance but higher $F_{40\%}$ when a wider prior on q is used). However, more complete exploration would be needed to understand this better.

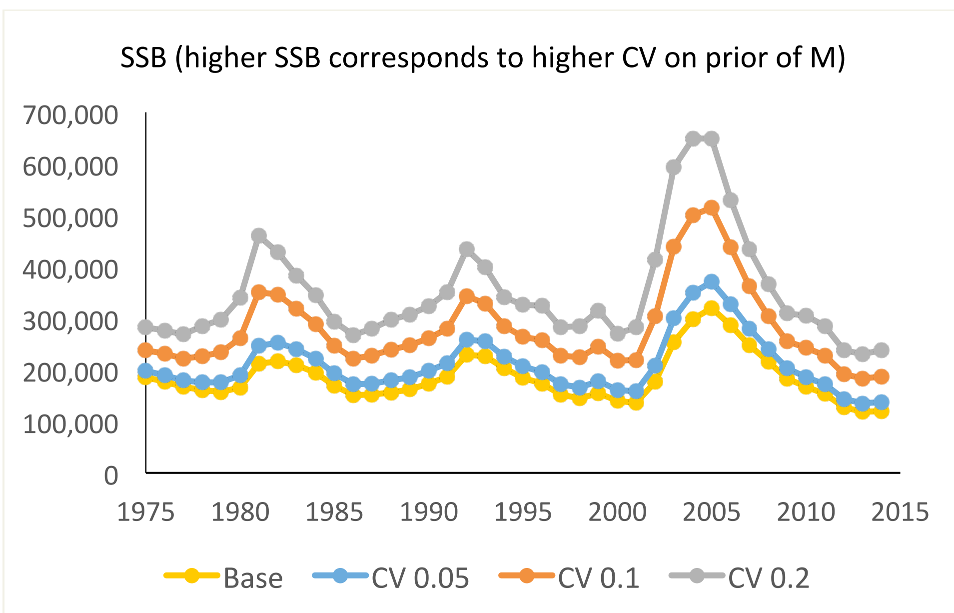
ToR 4. The incorporation of age differential natural mortality and the interaction with selectivity and survey catchability parameters.

The Atka mackerel assessment uses M=0.3, for all years and ages. This value was derived from Hoenig's (1983) method with a maximum age of 14 years. Some years ago, AFSC scientists explored alternative methods of estimating M for Atka mackerel, based on life history parameters. The value 0.3 was not inconsistent with the range of possible values obtained in that analysis and, hence, the value 0.3 was kept for M. About ten years ago there was also an attempt to estimate M within the stock assessment, but the results were considered unrealistic and, hence, this line of work was not pursued further at that time.

Some alternative possibilities for the treatment of M in this stock assessment were discussed during the review meeting. Estimating M of fish stocks is generally found difficult and the case of Atka mackerel seems no exception to this general rule. Some quick trial assessment runs were performed during the review meeting, estimating a separate M parameter (assumed constant over time) for each age. Three such runs were performed, with prior distributions centered at 0.3 (prior median) in all cases but with different CVs (0.05, 0.1 and 0.2). The figure below shows that the resulting estimates of M were always higher than 0.3, and increased for the 8+ ages; the shape estimated for M for the case with CV=0.2 does not seem very realistic (to my eye), with the peak in M at age 4.

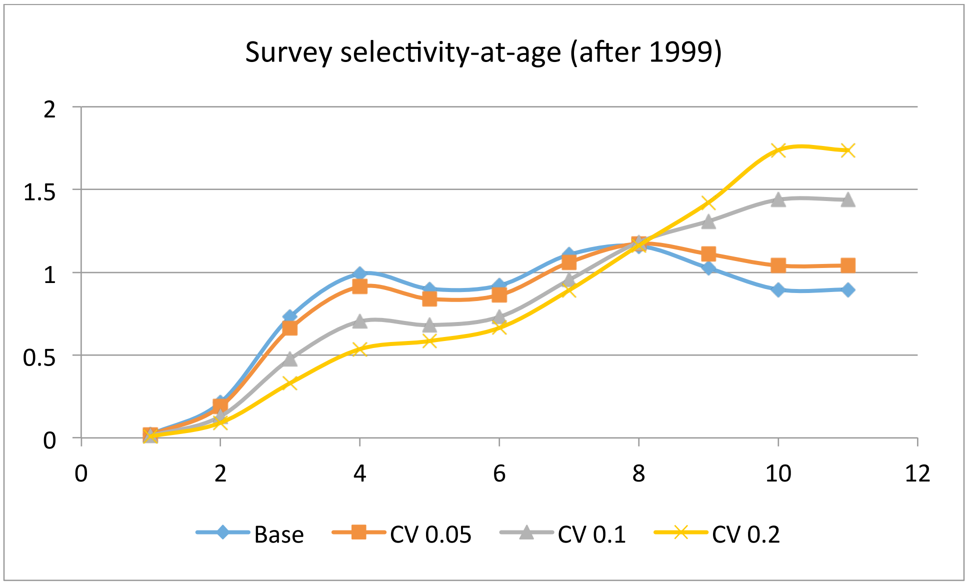


The wider the prior on M (i.e. the higher the CV of this prior), the higher were the estimated population sizes, as the following figure illustrates for SSB ("Base" represents the current assessment, with M fixed at 0.3).

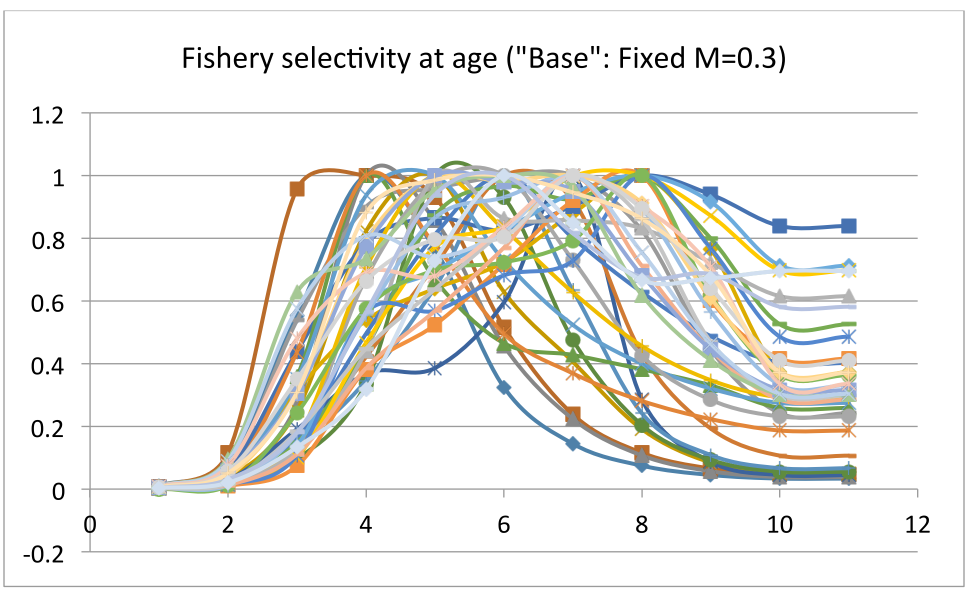


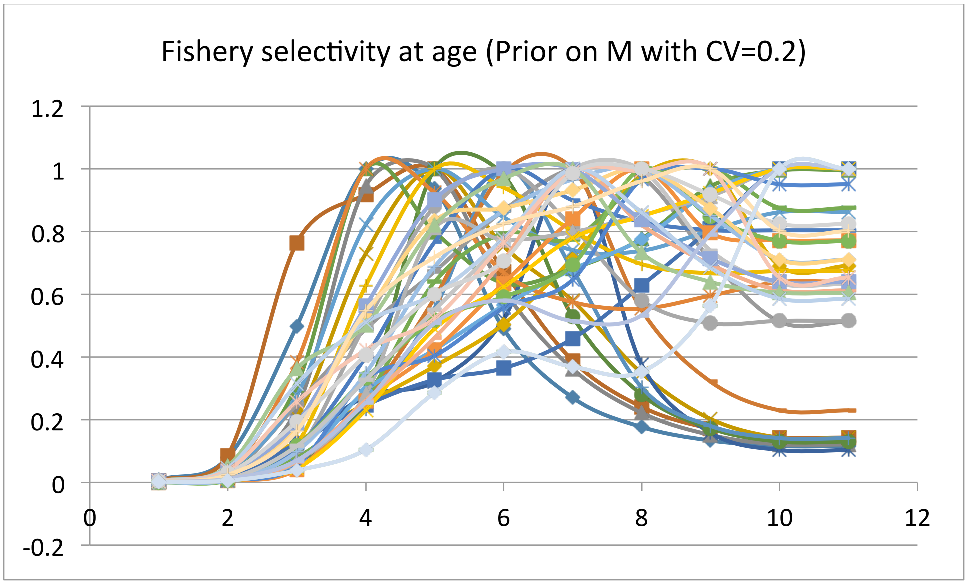
Unsurprisingly, the larger population sizes estimated under the bigger natural mortalities also corresponded to lower estimated survey catchability q (q is estimated at 1.20 in the base case, and at 1.09, 0.93 and 0.85 when the prior CV of M is assumed to be 0.05, 0.1 and 0.2, respectively); I note that q is calculated based on a normalized survey selectivity, where the average selectivity of ages 4-10 is equal to 1.

There is also a strong interaction between M and the shape of the survey selectivity. As M increases, the survey selectivity-at-age continues to increase over a wider range of ages, as illustrated in the figure below. I do not have sufficient knowledge to say whether the estimated selectivity curves are realistic; I would guess that the selectivity obtained in the case where the prior CV of M is 0.2 most likely is not realistic, but scientists at AFSC should have a much better understanding of this than me.

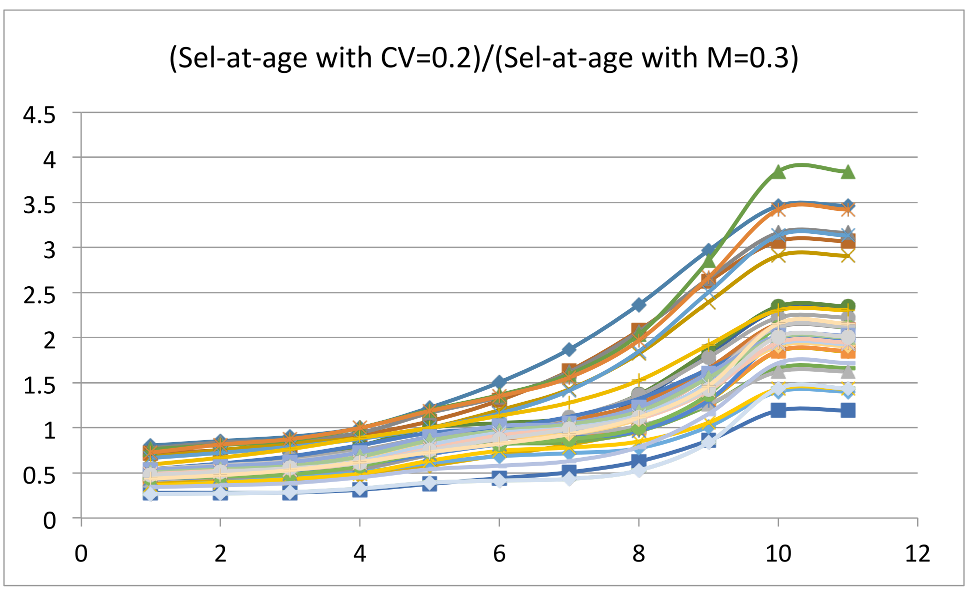


There is also an interaction between M and the shape of the fishery selectivity (with bigger M, as estimated in the case where the prior CV of M is 0.2, the fishery selectivity at older ages also increases with respect to what was found in the case with constant M=0.3 over all ages). This is illustrated in the two figures below (each line corresponds to selectivity in a year, and is normalized to have a maximum of 1 over the ages).





The following figure is a different way of looking at the same issue. Each line in the following figure still corresponds to one year, and is the ratio of the selectivity-at-age (in that year) obtained when the prior CV of M is 0.2 and when M is fixed at 0.3. Hence, each line in the following plot is the ratio of the corresponding lines (for the same year) of the two figures immediately above this paragraph. The overall message of this figure is the same obtained for the survey selectivity, i.e. when M is bigger, the differences between selectivity estimated for the younger and the older ages are larger.



In summary, the estimates of M are correlated with population size, survey catchability q, and the shape of the survey and fishery selectivity at age. Even though the explorations conducted during the review meeting on possible alternative specifications for M were quite quick, and there was no time to get into this in much depth, I find the analysis helps to understand the type of correlations that arise between the estimates of various key parameters and outputs of the stock assessment.

The value of M also has an effect on reference points. $F_{40\%}$ was calculated during the review meeting and seen to increase as the prior CV of M became larger (i.e. as the estimated value of M became higher). Thus, the treatment of M in the stock assessment seems to have the potential to influence stock perception and catch advice substantially and I suggest that careful examination would be needed before implementing any changes to this parameter.

A sensible alternative could be to consider an age-dependent M selected outside the assessment model. Obvious options are the Lorenzen model (e.g. Lorenzen 1996), or the M-at-age formulation suggested in the report of the natural mortality workshop held at AFSC in 2009 (the "best ad-hoc mortality model" from that report), see Brodziak *et al.* (2011). There was no time during the review meeting to explore these alternatives, but they seem like options worth exploring. M-at-age could selected in this way and treated as fixed in the assessment model, or perhaps M-at-age could be estimated in the assessment model using a tight prior centered around the values found in this way (i.e. with Lorenzen's or the "best ad-hoc mortality model").

It would also be interesting to examine the data that may be available to estimate predation mortality and consumption rates of Atka mackerel by its predators, although I understood that information in the Aleutians Islands area is sparse.

Conclusions and recommendations (in accordance with each ToR):

My conclusions, suggestions and recommendations were incorporated in the detailed discussions provided above for each of the ToRs. In this section I highlight main aspects in bullet point form.

ToR 1a: Use of fishery dependent and fishery independent data

- Understanding whether age frequency distributions (not just length frequency distributions) differ between western and eastern areas would be relevant, particularly given the geographical restrictions on the fishery in recent years due to Steller sea lions protection measures. During the review, we were told that no particular differences had been detected in the age composition data of different areas, but that this would be explored in more detail for future assessments. I agree that further examination would be useful.

- Given the patchy distribution of Atka mackerel, and the very large spikes encountered in the survey, it would be useful to explore if a more suitable method than a straight within-stratum average for computing an abundance index could be found. Mixture models or similar methods could be explored (see e.g. Thorson *et al.*, 2011, 2012). A more involved possibility would be to try and develop a habitat model, characterizing the features associated with the distribution of Atka mackerel and how these features are distributed throughout the survey area. If such a model could be developed, then more precise prediction of Atka mackerel abundance in areas/stations not sampled could be obtained.

- The following aspect was only mentioned in passing during the review meeting, but having thought about it afterwards, I think it would be worth exploring. I understood that the observation equation for the observed biomass index in the assessment model is log-normal with median equal to the model-predicted biomass index value. However, it seems to me that the survey index has been constructed to be an unbiased estimator of the model-predicted value and, therefore, it would seem more appropriate to assume the mean, rather than the median, of the log-normal observation equation is equal to the model-predicted value. I find it difficult to guess what the impact of this change would be on the stock assessment, but given the different CVs in different years (ranging from 14% to 35% during 1991-2012), I expect it will have some impact and I think it would be relevant to understand this.

ToR 1b: Population dynamics modeling and logic

- I did not find any gaps or inconsistencies in the population dynamics modeling methodology or logic. I suggest that providing more explanation and supporting documentation (references) for the methodology applied (essentially, maximum likelihood, penalized with multiple stochastic assumptions) would be useful. This could be provided in future assessment documents or as part of the AMAK documentation.

ToR 1c: Assessment uncertainties and their use in management advice

- For the observation equations in the assessment model, the CV for the survey biomass index and multinomial sample sizes for the commercial catch data appear to have been chosen based only on sampling variability and do not account for additional uncertainties in terms of how well the observed data may represent the true quantities. It could be interesting to explore what would happen if an extra component was added to the variability to represent departures between observed data and real quantities not already encapsulated by the sampling variability; this additional component would be a parameter to be estimated as part of the stock assessment. However, I do not regard this as urgent.

- From a scientific perspective, I consider the most appropriate treatment of uncertainty in management advice would be to realistically quantify assessment and projection uncertainty and then to have a management policy for what constitutes acceptable risk levels; the advice would then follow from the risk level specified in the policy, taking into account the (realistically quantified) assessment and projection uncertainty. I am aware that getting a truly realistic quantification of assessment and projection uncertainty is easier said than done and that managers are not always prepared to set risk levels. On the whole, I do not have any particular problem with the way management advice is currently formulated for the Atka mackerel stock, which provides a pragmatic way of dealing with the issues.

ToR 1d: Whether the assessment provides the best available science

- I consider the stock assessment to be consistent with best available science. I would like to stress that my comments in this report refer to aspects that I think would be interesting to explore, in order to try and gain additional understanding of those aspects (e.g. modeling methodologies or some specific features of the Atka mackerel assessment); some modifications to the stock assessment may follow after performing some explorations. There is, however, nothing that I feel needs to be urgently changed.

ToR 2: Time and age varying selectivity

- The basic idea, which is to model selectivity as a correlated process over ages and time, seems sensible to me, and the way in which the idea has been implemented in the Atka mackerel assessment also seems reasonable.

- Despite my overall positive comment in the previous bullet point, I suggest that a simulation-testing exercise to increase understanding of the properties of the method proposed would be useful. This would relate to the actual modeling of the selectivity over ages and time and to the method for estimating the standard deviation (σ_S) parameters. The simulation-testing could be similar to what was done for the WCSAM workshop held in Boston in 2013 (http://www.ices.dk/news-and-events/symposia/WCSAM-2013/Pages/Structure.aspx); see also Deroba *et al.* (2014).

ToR 3a: Survey estimates by management area and ABC split

- Based on a quick examination (details earlier in this report), the method used to split the Atka mackerel ABC between the three fishing districts, with relative weights of 1.5 between consecutive surveys, does not seem inappropriate and I feel it can continue to be used.

- As the assessment authors indicated during the review, I suggest waiting for the results of the working group specifically dealing with methods for these splits, as more appropriate ways to perform the split may be found.

ToR 3b: Survey catchability

- Assessment runs were conducted during the review meeting downweighting the survey biomass index data. Having thought about the results again after the meeting, I find it surprising that a lower stock biomass estimate was associated with a lower estimate of q and I wonder whether this result may be related to the fact that the log-normal observation equation for the survey has the model-predicted biomass index value as the median rather than the mean. I suggest exploring this issue further, repeating the same exploration conducted during the review meeting but keeping the same mean (instead of the same median) for the log-normal observation equation of the survey biomass index.

- Alternative assessment runs conducted during the review meeting, with wider priors on the survey catchability q, led to higher estimates of q (of around 1.8) and lower estimates of stock biomass than in the original stock assessment (which has a tighter prior on q); in all cases the prior was centered around a mean or median of approximately 1. I suggest further exploration of these issues, and provided some ideas for this in the discussion of this ToR earlier in the report.

- At present, overall stock levels do not seem well determined, and appear to depend on the prior assumptions made about q. It was said during the review meeting that a higher estimate of q could be a way to reconcile highly variable survey biomass indices with other sources of data that do not indicate so much inter-year variability in the population; this could be a feasible explanation for the high estimated q. Based on the information seen during the review, my impression is that the prior distribution on q currently used for the Atka mackerel assessment (with CV=0.2) provides a sensible compromise that allows reconciling what might be considered as realistic based on expert knowledge and the possibly not entirely consistent signals arising from the different data sources.

ToR 4: Natural mortality at age and interaction with selectivity and survey catchability parameters

- Alternative assessment runs conducted during the review meeting, estimating an age varying M (constant over time) within the assessment model. From the results of these runs, my conclusion is that the treatment of M in the stock assessment has the potential to influence stock perception and catch advice substantially and I suggest that careful examination would be needed before implementing any changes to this parameter.

- A sensible alternative could be to consider an age-dependent M selected outside the assessment model. Obvious options are the Lorenzen model (e.g. Lorenzen 1996), or the M-at-age formulation suggested in the report of the natural mortality workshop held at AFSC in 2009 (the "best ad-hoc mortality model" from that report), see Brodziak *et al.* (2011). There was no time during the review meeting to explore these alternatives, but they seem like options worth exploring. An M-at-age vector could selected in this way and treated as fixed in the assessment model, or perhaps the M-at-age vector could be estimated in the assessment model using a tight prior centered around the values found in this way (i.e. with Lorenzen's or the "best ad-hoc mortality model").

- It would also be interesting to examine the data that may be available to estimate predation mortality and consumption rates of Atka mackerel by its predators, although I understood that information in the Aleutians Islands area is sparse.

Appendix 1: Bibliography of materials provided for review

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(*) 2013 jack mackerel stock assessment. South Pacific Regional Fisheries Management Organization (SPRFMO). First report of the Scientific Committee, Annex 5.

(*) Statement of Work. External Independent Peer Review by the Center for Independent Experts. Bering Sea and Aleutian Islands Atka Mackerel Assessment.

Appendix 2: Copy of CIE statement of work

Attachment A: Statement of Work for Dr. Carmen Fernandez

External Independent Peer Review by the Center for Independent Experts

Bering Sea and Aleutian Islands Atka Mackerel Assessment

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Representative (COR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from *www.ciereviews.org*.

Project Description: The Alaska Fisheries Science Center (AFSC) requests a Center of Independent Experts (CIE) review of the Bering Sea and Aleutian Islands stock assessment for Atka mackerel. In the Aleutian Islands Atka mackerel are a key prey for several top trophic level consumers in the region. Of particular concern, Atka mackerel are a dominant prey item for the endangered Steller sea lion. In addition, Aleutian Islands Atka mackerel supports a valuable commercial fishery. In 2011, large scale changes to the Atka mackerel fishery were imposed as protection measures for Steller sea lions. These measures included large area closures and reduction in directed fishing quotas. Currently the Atka mackerel fishery is closed in the western Aleutians (representing about 34% of the quota). Because of their unique role in the Aleutian Island ecosystem and their importance to industry, reliable estimates of Atka mackerel biomass and trends are needed to provide informed catch recommendations. Several changes have been made to improve the assessment since the last CIE review. Recent model explorations have focused attention on alternative approaches to specifying selectivity, natural mortality, and age-specific survey catchability. We will be seeking advice on incorporating alternative approaches for the estimation of these key parameters. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Reviewers: Three CIE reviewers shall have the necessary qualifications to complete an impartial and independent peer review in accordance with the tasks and ToRs described in the SoW herein. The CIE reviewers shall have expertise in conducting stock assessments for fisheries management, and be thoroughly familiar with various subject areas involved in stock assessment, including population dynamics, separable age-structured models, harvest strategies, survey methodology, and the AD Model Builder programming language to complete the tasks of the scientific peer-review described herein. Each CIE reviewer is requested to conduct an impartial and independent peer review in accordance with the ToRs herein. The CIE reviewer's duties shall not exceed a maximum of 14 days conducting pre-review preparations with document review, participation in the panel review meeting, and completion of the CIE independent peer review report in accordance with the ToR and Schedule of Milestones and Deliverables.

Location of Peer Review: Each CIE reviewer shall participate and conduct an independent peer review during the panel review meeting scheduled at the Alaska Fisheries Science Center (AFSC) in Seattle, Washington during the dates of July 29-31, 2014.

Statement of Tasks: Each CIE reviewer shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Tasks prior to the meeting: The contractor shall independently select qualified reviewers that do not have conflicts of interest to conduct an independent scientific peer review in accordance with the tasks and ToRs within the SoW. Upon completion of the independent reviewer selection by the contractor's technical team, the contractor shall provide the reviewer information (full name, title, affiliation, country, address, email, and FAX number) to the contractor officer's representative (COR), who will forward this information to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The contractor shall be responsible for providing the SoW and stock assessment ToRs to each reviewer. The NMFS Project Contact will be responsible for providing the reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact will also be responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COR prior to the commencement of the peer review.

Foreign National Security Clearance: The reviewers shall participate during a panel review meeting at a government facility, and the NMFS Project Contact will be responsible for obtaining the Foreign National Security Clearance approval for the reviewers who are non-US citizens. For this reason, the reviewers shall provide by FAX (not by email) the requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/.

Pre-review Background Documents: Approximately two weeks before the peer review, the NMFS Project Contact will provide copies of stock assessment documents, survey reports, and other pertinent literature on a web site for the reviewers to conduct the peer review, and the COR will forward these to the contractor. The reviewers are responsible only for the pre-review documents that are delivered to the contractor in accordance to the SoW scheduled deadlines specified herein. The reviewers shall read all documents deemed as necessary in preparation for the peer review.

Tasks during the panel review meeting: Each reviewer shall conduct the independent peer review in accordance with the SoW and stock assessment ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs shall not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COR and contractor.** Each reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the stock assessment ToRs as specified herein. The NMFS Project Contact will be responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact will also be responsible for ensuring that the Chair understands the contractual role of the reviewers as specified herein. The contractor can contact the COR and NMFS Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Tasks after the panel review meeting: Each reviewer shall prepare an independent peer review report, and the report shall be formatted as described in **Annex 1**. This report should explain whether each stock assessment ToR was or was not completed successfully during the panel review meeting. Additional questions and pertinent information related to the assessment review addressed during the meetings that were not in the ToRs may be included in a separate section at the end of an independent peer review report.

The chairperson shall generate a Summary Report that compiles the points made by the three individual reviewers into one succinct document. The individual reports shall be appended to the Summary Report, thereby providing the complete detailed information from the individual reviewers.

<u>Contract Deliverables - Independent CIE Peer Review Reports</u>: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting at Seattle, Washington during July 29-31, 2014.
3) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than August 15, 2014, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional

Coordinator, via email to Dr. David Die at ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

23 June 2014	CIE sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
7 July 2014	NMFS Project Contact sends the stock assessment report and background documents to the CIE reviewers.
29-31 July 2014	Each reviewer shall conduct an independent peer review during the panel review meeting in Seattle, Washington
15 August 2014	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
29 August 2014	CIE submits CIE independent peer review reports to the COR
5 September 2014	The COR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COR within 10 working days after receipt of all required information of the decision on changes. The COR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The CIE report shall address each ToR as specified in **Annex 2**,

(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The COR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed. The CIE independent report shall be an independent peer review of each ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

Bering Sea and Aleutian Islands Atka Mackerel Assessment

All reports shall address the following points.

1. The strengths and weaknesses of the modeling efforts for the Bering Sea and Aleutian Islands Atka mackerel assessment and harvest recommendations. Specifically, the review shall evaluate:
    a) The analysts' use of fishery dependent and fishery independent data sources in the assessments;
    b) Gaps or inconsistencies in the population dynamics modeling methodology or logic;
    c) How assessment uncertainties may best be applied for management advice; and
    d) Whether the assessments provide the best available science.

Additionally, the review shall (to the extent practical) evaluate and provide advice on:

2. The specification of time-varying and age-specific selectivity parameters

3. The treatment and application of survey data; specifically

    a. Survey biomass estimates by management areas as used for quota apportionments; this stock forms dense patchy schools resulting in high variability

    b. Survey catchability

4. The incorporation of age differential natural mortality and the interaction with selectivity and survey catchability parameters

    The AFSC will provide copies of stock assessment documents, survey reports, and other pertinent literature on a web site.

Annex 3: Agenda for

CIE Bering Sea/Aleutian Islands Atka mackerel Stock Assessment Review

NMFS Alaska Fisheries Science Center
7600 Sand Point Way NE, Building 4, **Room 2039,** Seattle, Washington

Article I. AGENDA *JULY 8 VERSION* July 29-31, 2014

Tuesday July 29th

9:00	Welcome and Introductions	**Martin Dorn (Chair)**
9:15	**Overview** (management, fishery, biology descriptions)	
	Management control rules and general modeling approach	**Jim Ianelli**
	Atka mackerel fishery and life history	**Sandra Lowe**
10:30	*Break*	
10:45	**Observer** sampling and coverage (1 hr)	**FMA TBD**
11:45	***Lunch***	
13:00	**Age and growth** (1 hr)	**Age and Growth TBD**
14:00	**Bottom trawl survey** (1 hr)	**Ned Laman, Susanne McDermott**
15:00	*Break*	
15:15	Aleutian Islands **ecosystem** overview (45 min)	**Stephani Zador**
16:00	Assessment model (AMAK) details	
17:00	Meeting adjourns for the day	

Note *At the end of each presentation and after the panel has had an opportunity for questions, we will solicit brief public comment and questions as moderated by the Chairperson*

Wednesday July 30th

9:00	Atka Mackerel stock assessment	**Sandra/Jim**
10:45	*Break*	
11:00	Review of stock assessment issues: incorporation of uncertainty, time-varying and age-specific selectivity, survey estimates by management area as used for quota apportionments, survey catchability, age differential *M* and interactions with selectivity and survey catchability parameters	
12:00	*Lunch*	
13:00	Discussion of proposed assessment model changes	
15:00	Meeting adjourns for the day (afternoon reserved to work on model runs)	

Thursday July 31st

9:00	Evaluation of alternative model configurations
	Reviewer discussions with assessment authors
12:00	***Lunch***
1:00	Reviewer discussions with assessment authors as needed (continued)
3:00	Report writing. AFSC analysts will be available to respond to requests and answer questions

Appendix 3: Panel membership or other pertinent information from the panel review meeting

Panel members (alphabetical):

- Carmen Fernández, Spain
- Jean Jacques Maguire, Canada
- Stephen Smith, Canada